Sealing NatureWorks® PLA Thermoformed Containers with PVC Shrink Bands

Shrinkable PVC bands and preforms have been developed and become the largest and simplest way to make a secure and tamper evident seal on a thermoformed lidded container. The bands are readily available, low cost, clear, and tough. They also have a high degree of shrink at a relatively low temperature. Unfortunately, the shrinkage temperature of these bands and preforms is not low enough to be able to use on NatureWorks PLA containers without some restrictions. In general, NatureWorks, LLC recommends the use of a PLA shrink band or preform to seal amorphous PLA containers. Only a PLA shrink band has the correct shrink temperature profile to be able to work worry free with an amorphous PLA container. However, there are circumstances when due to band or preform availability or price, a PVC band is preferred over a PLA band. In these cases, it may be possible to use a PVC band provided the packer is aware of the differences in the materials.

To understand how to effectively use a PVC band on a NatureWorks container, one must understand the mechanism of shrink band sealing. Every plastic material has a unique temperature where the plastic changes from rigid, stiff or glassy nature to a soft, pliable or rubbery state. This temperature is referred to as the glass transition temperature or Tg of the material. Most commercial rubbers, have a glass transition temperature well below room temperature so these materials are always observed to be rubbery or elastic at room temperature. Plastics used in construction or rigid packaging such as polystyrene have a glass transition temperature above room temperature so they are normally seen in their glassy state.

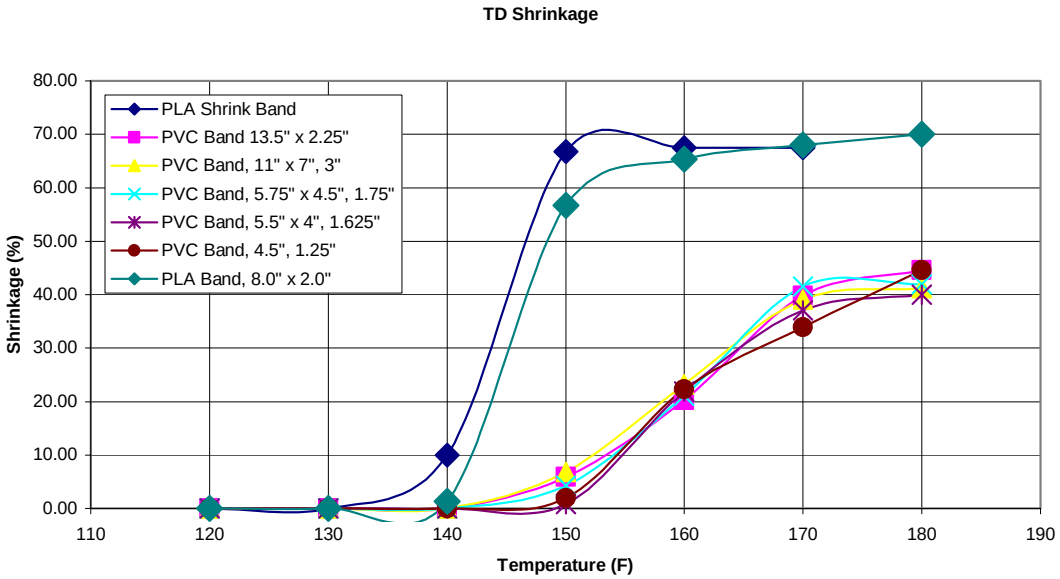
Both PVC and NatureWorks PLA have their Tg above room temperature and so they are quite stiff and rigid at room temperature. When they are heated above the Tg, stretched and subsequently cooled to below their Tg while being restrained, they form a rigid material with a stored memory or what is called residual stress. That is, they have a memory of their original shape and will try to return to that shape if the temperature of the plastic is raised back above its Tg. This is exactly how shrink bands are produced and used.

While this is an intended result for shrink bands, it is an unintended side effect during the production of thermoformed containers. As a sheet of plastic is heated and stretched into a mold to produce a container, it also develops residual stresses. In a shrink band, the amount of residual stresses in the band is directly proportional to the amount of stretch put into the band. In a thermoformed container, the amount of residual stress is dependent upon the shape of the container, the forming speed, the type of thermoformer used to make the container, the temperature of the cooling mold and finally the temperature of the sheet just prior to forming. Some parts have little to no residual stresses while other parts can have a significant amount of residual stresses. In the case of low residual stress part, raising the temperature of the part will result in a softening of the part but generally, the dimensions of the part will remain unchanged. However, in a part with a high amount of residual stresses, the part will experience significant deformation when the part sees a temperature near its Tg as the plastic will want to return to its previous shape.

The shrinkage temperature of a plastic band is a function of both its Tg and the level of residual stresses. Bands made from PVC have a higher shrink temperature than bands made from PLA due to a higher Tg and a reduced level of inherent residual stresses. Therefore, a band of PVC will need to be raised to a higher temperature than a band of PLA before either of them starts to shrink. Additionally, a band of PLA will shrink to a higher degree than a band of PVC. The plot below shows the level of shrinkage (as a percent of original size) as a function of the band temperature. Typically, a shrink band needs to shrink by about 30% to form a good tight seal on a container. The chart clearly indicates that a PVC shrink band needs to be heated approximately 20 degrees hotter than a PLA band to achieve a 30% shrinkage rate.

In most cases, this is not an issue as most thermoformed containers are made from polystyrene, polyester or polypropylene, all of which have a much higher shrink temperatures than either PLA or PVC. However, if the

container is made from NatureWorks PLA and the band is made from PVC, the shrink temperature of the band is higher than that of the container and therefore problems could occur.



Fortunately, a shrink band is thinner than almost any section of a thermoformed container and therefore, the possibility exits that during the travel through the oven, the band reaches its shrinking temperature before the container reaches its shrinking temperature. This is because the rate of heating of a band or part is proportional to the thickness of the part. By carefully controlling the heating rate in the oven, the band will shrink around the lid of the container before any deformation can occur and the final package will be secure and visually appealing.

Specific recommendations on oven temperatures, belt speeds and oven configurations are impossible to list here due to the large number of designs used in the industry. However, the following is a list of guidelines that one should follow in order to maximize the chances of success when using a PVC band on a NatureWorks container.

Band Selection

1) Use the thinnest gauge band possible as a thinner band will heat up faster than a thick band.
2) If your shrink band supplier offers bands with different percentages of shrink rates, choose the band with the highest shrinkage as this is an indication of higher residual stresses and the lowest possible shrink temperature.

Oven Settings

1) Use the lowest oven temperature possible to achieve shrinkage of the band. Because there are a large number of heat tunnels and designs it is difficult to set a recommended temperature setting for shrink bands and preforms. For the widely used tunnels know as Overwrap Tunnels it has been found that a tunnel setting of 280 to 290F (~140°C) and a tunnel dwell time of 3.5 to 4 seconds works to shrink both PVC and PLA bands and preforms.
2) Direct any blowers or air nozzles in the oven directly at the shrink band to increase convective heat transfer to the band.
3) Minimize heat on the conveyor belt or better yet, cool the belt during its return to the oven entrance.

Container Selection

1) Use containers with the lowest possible level of residual stresses in the part.
2) Use containers that have the thinnest section at least 10 times thicker than the thickness of the shrink band.

3) If one area of a container deforms at the lowest possible oven temperature for the PVC band to shrink, identify that area and work with the container supplier to reduce the residual stresses in that area or increase the wall thickness in that area.
4) If the bottom of the container is deforming, consider cooling the belt while it travels back to the oven entrance. Alternatively, consider placing insulating pads under the container to raise them off the metal belt. Also consider replacing a metal roller or metal mesh belt with a nylon mesh or similar type belt.

While NatureWorks, LLC recommends using PLA shrink bands for NatureWorks containers, in some cases, it is possible to use a PVC shrink band if the above precautions are taken. However, some container designs inherently have high levels of residual stresses within the thin areas and may not be able to withstand the oven temperature necessary to shrink the PVC band without deformation. In these cases, PLA bands are the only commercially viable option for sealing.

Safety and Handling Considerations
Material Safety Data (MSD) sheets for PLA polymers are available from NatureWorks LLC. MSD sheets are provided to help customers satisfy their own handling, safety, and disposal needs, and those that may be required by locally applicable health and safety regulations, such as OSHA (U.S.A.), MAK (Germany), or WHMIS (Canada). MSD sheets are updated regularly; therefore, please request and review the most current MSD sheets before handling or using any product.

The following comments apply only to PLA polymers; additives and processing aids used in fabrication and other materials used in finishing steps have their own safe-use profile and must be investigated separately.

Hazards and Handling Precautions
PLA polymers have a very low degree of toxicity and, under normal conditions of use, should pose no unusual problems from incidental ingestion, or eye and skin contact. However, caution is advised when handling, storing, using, or disposing of these resins, and good housekeeping and controlling of dusts are necessary for safe handling of product. Workers should be protected from the possibility of contact with molten resin during fabrication. Handling and fabrication of resins can result in the generation of vapors and dusts that may cause irritation to eyes and the upper respiratory tract. In dusty atmospheres, use an approved dust respirator. Pellets or beads may present a slipping hazard. Good general ventilation of the polymer processing area is recommended. At temperatures exceeding the polymer melt temperature (typically 170ºC), polymer can release fumes, which may contain fragments of the polymer, creating a potential to irritate eyes and mucous membranes. Good general ventilation should be sufficient for most conditions. Local exhaust ventilation is recommended for melt operations. Use safety glasses if there is a potential for exposure to particles which could cause mechanical injury to the eye. If vapor exposure causes eye discomfort, use a full-face respirator. No other precautions other than clean, body-covering clothing should be needed for handling PLA polymers. Use gloves with insulation for thermal protection when exposure to the melt is localized.

Combustibility
PLA polymers will burn. Clear to white smoke is produced when product burns. Toxic fumes are released under conditions of incomplete combustion. Do not permit dust to accumulate. Dust layers can be ignited by spontaneous combustion or other ignition sources. When suspended in air, dust can pose an explosion hazard. Firefighters should wear positive-pressure, self-contained breathing apparatuses and full protective equipment. Water or water fog is the preferred extinguishing medium. Foam, alcohol-resistant foam, carbon dioxide or dry chemicals may also be used. Soak thoroughly with water to cool and prevent re-ignition.

Disposal
DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. For unused or uncontaminated material, the preferred options include recycling into the process or sending to an industrial composting facility, if available; otherwise, send to an incinerator or other thermal destruction device. For used or contaminated material, the disposal options remain the same, although additional evaluation is required. (For example, in the U.S.A., see 40 CFR, Part 261, "Identification and Listing of Hazardous Waste.") All disposal methods must be in compliance with Federal, State/Provincial, and local laws and regulations.

Environmental Concerns
Generally speaking, lost pellets are not a problem in the environment except under unusual circumstances when they enter the marine environment. They are benign in terms of their physical environmental impact, but if ingested by waterfowl or aquatic life, they may mechanically cause adverse effects. Spills should be minimized, and they should be cleaned up when they happen. Plastics should not be discarded into the ocean or any other body of water.

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